LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA18 | Stoneleigh, Kenilworth and Burton Green

Flood risk assessment (WR-003-018)

Water resources

November 2013

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Department for Transport

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Appendix WR-003-018

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Flood Risk Assessment	003
Community forum area:	Stoneleigh, Kenilworth and Burton Green	018

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List of acronyms

A full list of acronyms and terms will be compiled for the draft and final Environmental Statement (ES), those listed below are used within this document:

CC	Climate Change
CoCP	Code of Construction Practice
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
ES	Environmental Statement
FEH	Flood Estimation Handbook
FMfSW	Flood Map for Surface Water
FRA	Flood Risk Assessment
HS2	High Speed 2
IH124	Institute of Hydrology Report No 124
LEMP	Local Environmental Management Plan
LiDAR	Light Detection and Ranging
LWM	London West Midlands
MPAT	Mid Point Autotransformer Substation
NPPF	National Planning Policy Framework
OS	Ordnance Survey
PFRA	Preliminary Flood Risk Assessment
ReFH	Revitalised Flood Hydrograph
SFRA	Strategic Flood Risk Assessment
SMR	Scope and Methodology Report
SuDS	Sustainable Drainage Systems
2D	Two dimensional

1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment (FRA) appendices comprise of four parts. The first of these is a route-wide appendix (Appendix WR-001-000).

1.1.2 Three specific appendices for each community forum area (CFA) are also provided. For the Stoneleigh, Kenilworth and Burton Green area (CFA18) these are:

- a water resources assessment (Volume 5, WR-002-018);
- a FRA (i.e. this appendix); and
- a river modelling report (Volume 5, WR-004-011).

1.1.3 Maps referred to throughout the water resources and FRA appendices are contained in the Volume 5 Map Book – Water Resources.

1.2 Scope of this assessment

1.2.1 This FRA considers the assessment of flood risk in this study area, which is defined as the area within 1km of the route centre line within CFA18. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 This FRA presents baseline (current day) flood risk and post-construction flood risk as a result of the Proposed Scheme and has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of the document is on the change in risk status to local receptors, particularly existing infrastructure.

1.2.3 A risk-based methodology has been adopted through the application of the source-pathway-receptor model. This model has been used to identify the cause of 'sources' of flooding to and from a development. The identification is based on a review of local conditions and consideration of the effects of climate change.

1.2.4 In order for there to be a flood risk, all the elements of the model (a flood source, a pathway and a receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model, for example by removing the pathway or receptor.

1.2.5 Receptors may include people and their properties, business and infrastructure, and the built and natural environment within the range of the flood source which are connected to the source of flooding by a pathway.

[1] Department for Communities and Local Government (2012) *National Planning Policy Framework*.

1.2.6 This FRA has been completed to inform the Environmental Statement (ES) for the works, which will be a key part of the HS2 hybrid Bill submission required for the Proposed Scheme. The hybrid Bill is necessary for powers to build the railway, powers to buy land and for planning consent.

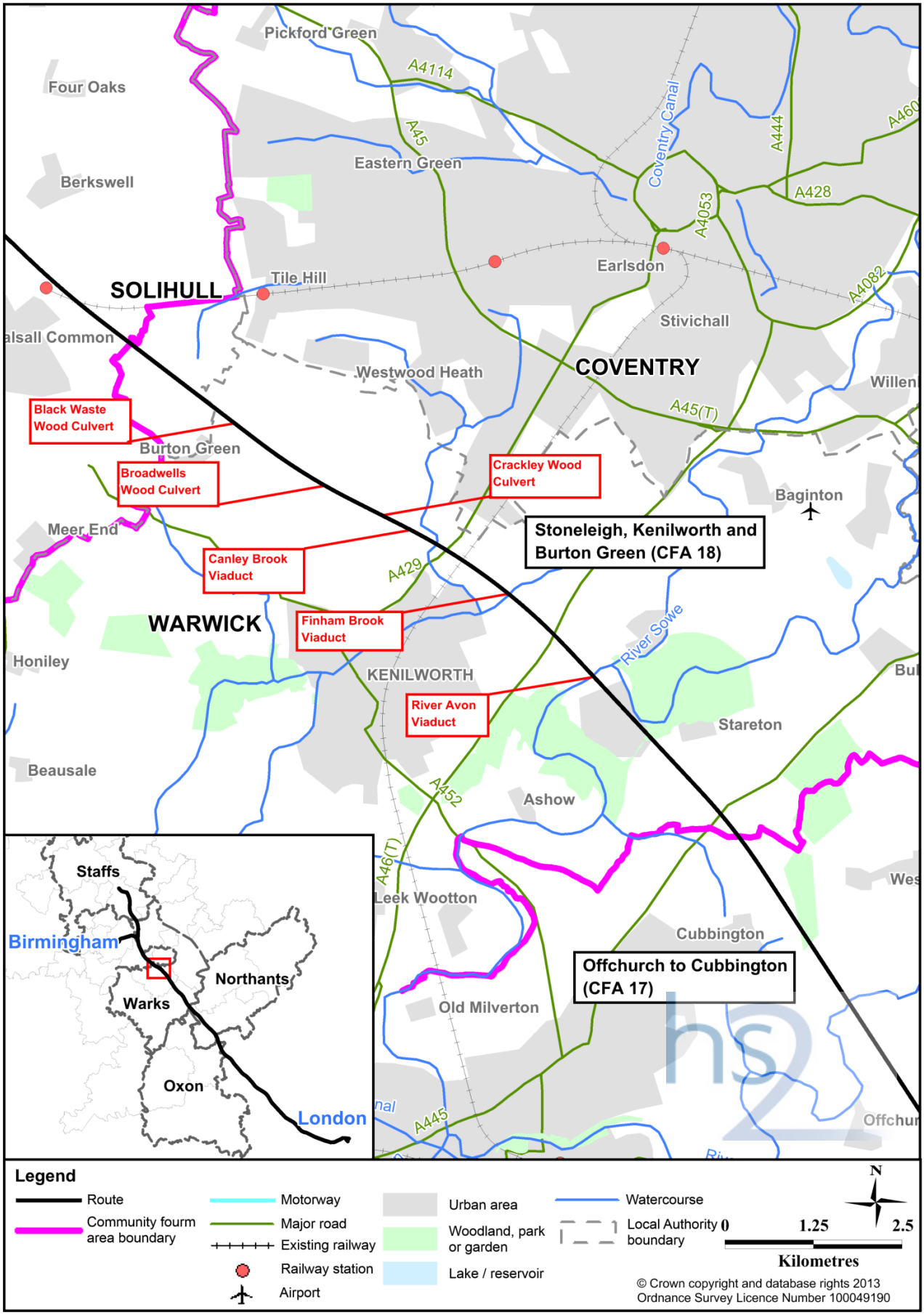
1.2.7 The Proposed Scheme will cross numerous surface water features within this study area, which are the River Avon, Finham Brook and Canley Brook.

1.3 Location

1.3.1 In this FRA the study area covers an 11.2km section of the Proposed Scheme in the county of Warwickshire, where it passes south-west of Coventry. It extends from near Furzen Hill Farm to Beechwood. The study area includes land within the communities of Stoneleigh, Kenilworth, Leek Wooton, Castle Green, Coventry and Burton Green.

1.3.2 A location plan of the Proposed Scheme within this study area is shown on Figure 1.

Figure 1: Location plan



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewers) in the short or medium term. Stored rainfall, either naturally, in aquifers (groundwater) and natural lakes, or artificially impounded in reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea. However given the inland location of this study area, this final source of flooding does not pose a risk.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 In general, receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the route centre line. However any receptors beyond this where a significant impact was expected were considered in this assessment. The Proposed Scheme includes all associated temporary and permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is required as part of the design to prevent an increase in flood risk in line with recommendations in the NPPF.

2.1.4 The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme will ensure that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

2.1.6 The FRA defines the baseline flood risk and vulnerability of receptors. This is used to define the value, importance and significance of effects which is provided within the ES.

[2] Department for Communities and Local Government (2012) *National Planning Policy Framework Technical Guidance*.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water/ overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	
Groundwater[5]		Very low-low	Moderate	High-very high	
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	
Artificial sources[7]	Outside of inundation mapping/no pathway exists	Within inundation mapping/pathway exists			

2.3 National planning policy framework

2.3.1 This assessment of flood risk makes use of the NPPF which is the Government's planning policy in relation to development and flood risk. It is set out within the NPPF that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere. The NPPF requires that proposed development located within Flood Zones 2 and 3 is assessed in relation to flood risk. This includes both flood risk to the development and any increases in flood risk elsewhere as a result of the development, with an allowance for climate change.

2.3.2 Methods used to ensure that development is at the lowest possible risk and that the development is safe without causing an increased risk elsewhere includes the application of the Sequential and Exception Tests. However, the Sequential Test has been considered as part of the overview FRA for the Proposed Scheme Volume 3 of the ES.

[3] River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.
[4] Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).
[5] Groundwater flood risk taken from local flood risk assessment reports.
[6] Identified using the Severn Trent Water's assets network.
[7] Risk from reservoir flooding identified using the Environment Agency reservoir inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

Flood zone classification

2.3.3 The NPPF splits the Environment Agency's Flood Map into three separate Flood Zones. These Flood Zones should be used in determining the appropriateness of proposed development uses and they represent flooding without flood defences in place.

2.3.4 The Flood Zones are defined as:

- Flood Zone 1 – Areas with a 'low probability' of flooding and where the annual probability of flooding is lower than 0.1% for either river or sea flooding. The NPPF imposes no constraints upon the type of development within Flood Zone 1;
- Flood Zone 2 – Areas with a 'medium probability' of flooding and where the annual probability of flooding is between 0.1 and 1.0% for river flooding or between 0.5 and 0.1% for sea flooding. The NPPF recommends that Flood Zone 2 is suitable for most types of development with the exception of 'highly vulnerable' land uses; and
- Flood Zone 3 – Areas with a 'high probability' of flooding and where the annual probability of flooding is 1.0% or greater for river flooding or 0.5% or greater for sea flooding. The NPPF recommends that appropriate development is based upon a further classification of Flood Zone 3: 3a high probability and 3b functional floodplain (where water has to flow or be stored in times of flood).

2.4 Local flooding planning policy documents

2.4.1 The local policies for this study area with implications in relation to flood risk are:

- Warwick District Local Plan 2007[8] – Policy DP11. Drainage is the principal policy of relevance to the management of surface-water flow. The policy advocates the use of Sustainable Drainage Systems (SuDS) for the disposal of surface water. Where the use of SuDS is not possible, the policy requires an alternative solution that does not increase the risk of flooding or environmental problems;
- Warwick District Local Plan 2007 – Policy DP2. Amenity is not specific in citing the causes of potential impacts on amenity, but states that development that will have an unacceptable impact on the amenity of nearby users and residents will not be permitted – this could be considered applicable to flooding; and
- Solihull Unitary Development Plain (UDP) 2006[9] – Policy ENV 21. Development in Floodplains states that development within a floodplain will only be permitted provided that it does not reduce the capacity of the floodplain; and its location is not liable to flooding. The policy reinforces national guidance in stating that essential infrastructure is the only type of built development that may be permitted in such a location.

[8] Warwick District Council (2007). *Warwick District Local Plan 2007*.
[9] Solihull Metropolitan Borough Council (2006). *Solihull Unitary Development Plan (UDP)*.

2.4.2 The Warwick District Strategic Flood Risk Assessment (SFRA)[10] and the Warwickshire Preliminary Flood Risk Assessment (PFRA)[11] aid the councils in preparing sustainable policies for the long-term management of flood risk and improving existing emergency planning procedures. The SFRA and PFRA is used as an evidence base to promote the location of future development primarily in low flood risk areas. The SFRA and PFRA have been used to inform this FRA.

2.5 Historical sources of flooding

2.5.1 The historical flooding incidents which have occurred either at the location of the route or in close proximity, have been determined as part of this FRA. These areas of historical flooding have been identified because places which have flooded in the past may be more susceptible to flooding in the future. Two sources of data relating to historical flooding have been used: local authority information (the relevant SFRA and PFRA) and extents of historical sources of river flooding as provided by the Environment Agency.

2.6 Flood risk approach

River flooding approach

Crossing locations

2.6.1 To determine the river flood risk at locations where the route crosses watercourses and to identify any changes in flood risk as a result of the Proposed Scheme, either existing hydraulic models have been used where available or new hydraulic models have been constructed. Where new models were required flows have been determined in line with current flood estimation guidelines[12].

Flow estimation

2.6.2 The majority of the watercourses that will be crossed by the route within this study area have no known detailed modelling available. Where Flood Zones are associated with these watercourses, the outlines have been determined through the use of broad-scale topographic data, which are considered to be a rough guide when determining areas at risk of flooding and hence have not been used for the design of engineering works. There are other watercourses which have no associated Flood Zones. Flows for these watercourses, at the location of the proposed crossing, have been determined for the 1 in 20 (5%), 1 in 100 (1%), 1 in 100 (1%) with a 20% allowance for climate change and 1 in 1000 (0.1%) annual probability events.

2.6.3 A quick estimation of flow was produced at the crossing locations using the Revitalised Flood Hydrograph model (ReFH) where the contributing catchments were represented within the Flood Estimation Handbook (FEH) CD-ROM[13] (such as at Crackley Wood culvert). A FEH calculation record for the estimation of flow using ReFH is provided in the river modelling report (Volume 5, WR-004-011).

[10] Warwick District Council (2013).*Warwick Level 1 Strategic Flood Risk Assessment. Volume 1* Produced by Mouchel.
[11] Warwickshire County Council (2011). *Warwickshire Preliminary Flood Risk Assessment*. Completed by Royal Haskoning on behalf of Warwickshire County Council.
[12] Environment Agency (2012) *Flood estimation guidelines*.
[13] Centre for Ecology and Hydrology (2009) *FEH CD-ROM Version 3*, ©NERC (CEH).

2.6.4 Small catchments (normally less than approximately 0.5km^2), such as at the Broadwells Wood culvert and the Black Waste Wood culvert, are not represented on the FEH CD-ROM and hence it is not possible to either produce a catchment boundary or determine catchment descriptors (required for the estimation of flow) from this source. For crossings where the watercourse is not represented within the FEH CD-ROM, a scaling method based on area, in line with the flood estimation guidelines was carried out. Contributing catchment areas at crossing locations were determined using topographic and Ordnance Survey (OS) mapping; in areas of uncertainty slightly larger catchments were defined as a conservative approach. The flows estimated through the use of ReFH for the catchments in the northern section of the Proposed Scheme were used to determine a scaling factor. The greatest flow per km^2 was used as a scaling factor for the catchments in this study area which were manually determined. An error allowance of 10% was also applied to reduce the risk of underestimating flows.

2.6.5 Where pre-existing modelling was available for watercourses, such as at the River Avon viaduct, Finham Brook viaduct and Canley Brook viaduct, the hydrology was obtained from these models. Further details of the hydrology associated with the pre-existing models are provided in the river modelling report (Volume 5, WR-004-011).

Modelling approach

2.6.6 To assess the impact of the proposed River Avon crossing, the existing hydraulic model created for the River Avon Flood Risk Mapping Study[14], was used. To assess the impact of the proposed Finham Brook crossing, an existing hydraulic model created for the Kenilworth Hazard Mapping Study[15] was used. To assess the impact of the proposed Canley Brook crossing, an existing hydraulic model created for the Hazard Mapping Study for Coventry[16] was used. These models were run for the baseline (current) scenario and for the Proposed Scheme scenario. At the other three crossings in this study area, suitable models were not available and therefore new hydraulic models were built utilising the new high resolution Light Detection and Ranging (LiDAR) data collected for the purposes of the Proposed Scheme. Further detail in relation to the hydraulic modelling is included in the river modelling report (Volume 5, WR-004-011).

2.6.7 The inflow boundaries were mostly applied as steady state flows with unsteady flows applied for certain watercourses. For watercourses with floodplain attenuation such as ponds and lakes or significant obstructions to flow (e.g. due to embankments), the inflows were modelled using unsteady state hydrographs. These models were run at longer durations covering the period of the hydrograph and attenuation. The resulting baseline (current) models were run for the 1 in 100 (1%) annual probability with an allowance climate change and 1 in 1000 (0.1%) events over a range of durations depending upon the flow conditions.

2.6.8 The Proposed Scheme models included either viaducts or culverts depending on the scheme design. The railway embankments were represented by modifying the model

[14] Environment Agency (2010) *River Avon Flood Risk Mapping Study*. Completed by Halcrow and JBA Consulting on behalf of the Environment Agency.
[15] Environment Agency (2011) *Kenilworth Hazard Mapping Study*. Completed by JBA Consulting on behalf of the Environment Agency.
[16] Environment Agency (2011) *Hazard Mapping Study for Coventry*.

Digital Terrain Model (DTM) at those locations. The 1 in 100 (1%) annual probability with an allowance for climate change peak flood levels upstream of the crossings were compared to the baseline (current) levels to assess the change in flood risk. The 1 in 1000 (0.1%) annual probability peak levels were extracted to inform on the vertical alignment of the track.

River flood risk elsewhere along the route

2.6.9 In addition to watercourse crossings, there are sections of the route which are located in areas potentially at risk of river flooding. These have been identified through the use of the Environment Agency Flood Zone mapping. This mapping has been used in preference to SFRA mapping as it is considered more up to date and hence likely to best reflect areas at risk. River flood risk to these sections of the route needs to be determined both to prevent an unacceptable level of risk to the Proposed Scheme and to prevent it increasing flood risk as result of a reduction in floodplain storage.

Summary of river flooding approach

2.6.10 Due to the number of river crossings, varying complexities, and the amount of data and information available for each, at some locations the modelling approach is highly specific. These locations have been reported as such and further information is included in the river modelling report (Volume 5, WR-004-011).

Surface water flood risk

2.6.11 The baseline (current) assessment of surface water flood risk was completed using the Flood Maps for Surface Water (FMfSW). The maps utilised for this assessment are:

- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.1m deep;
- 1 in 30 (3.3%) annual probability and surface water flooding greater than 0.3m deep;
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.1m deep; and
- 1 in 200 (0.5%) annual probability and surface water flooding greater than 0.3m deep.

2.6.12 This mapping identified sections of the route which currently are at specific risk from surface water flooding. The risk classification assigned at each location is dependent on which FMfSW the receptor is located within.

2.6.13 The Proposed Scheme has the potential to interrupt surface water flow which would require mitigation to prevent an increase in flood risk. In addition, other design elements such as landscaping will alter the permeability of the ground and hence modify sections of the surface water catchments. The assessment involved determining the land drainage catchments, surface water run-off from these catchments and the capacity of SuDS and culverts.

2.6.14 Land drainage catchments were identified using topographic data (primarily 5m contours, or 1m contours on small or unclear catchments). The assumption was made that linear features such as roads and railways do not act as a cut off for overland flow.

2.6.15 The calculation of Greenfield run-off rates from existing catchments was undertaken using the online SuDS tool[17]. A growth factor of 30% was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during this event with an allowance for climate change. A factor of 62% (based on calculations using the Flood Studies Supplementary Report 14[18]) was applied to the 1 in 100 (1%) annual probability rainfall event to determine the flow during the 1 in 1000 (0.1%) annual probability event.

2.6.16 Run-off from modified sections of the catchment as a result of the Proposed Scheme (e.g. landscape areas) which alter the permeability was determined using the Institute of Hydrology 124[19] (IH124) methodology.

2.6.17 Storage volumes were calculated using the online SuDS tool[17] assuming that landscape areas will be impermeable. The storage volumes required were taken to be the sum of the attenuation and long term storage as a conservative approach.

2.6.18 The calculations for the proposed drainage design have been completed in line with the requirements in Volume 1, Section 9.14.

Groundwater flood risk

2.6.19 Groundwater bodies and aquifers present within a 1km buffer of the area of temporary and permanent works have been identified and named on available web-based mapping data for the purposes of the Proposed Scheme.

2.6.20 Field investigations have not yet been undertaken.

Sewer systems flood risk

2.6.21 The risk of flooding from the sewer network has also been addressed as part of this assessment. The sewer network data was provided for this assessment by the relevant water company, Severn Trent Water, to determine locations of the route and other design elements which will be located at areas of risk.

Other sources of flood risk

2.6.22 Reservoir flood risk was assessed using the reservoir inundation maps as shown on the Environment Agency website[20]. The purpose was to identify areas along the route that were at risk of flooding if any reservoirs in the vicinity were to fail.

2.6.23 Canals were identified as another source of potential flood risk, and so canals that crossed certain sections of the route were identified in the assessment.

[17] HR Wallingford (2013) UK Sustainable Drainage Guidance and Tool. The Greenfield run-off estimation for sites tool. http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrunoff.aspx
[18] Institute of Hydrology (1983), *The Flood Studies Supplementary Report Number 14*.
[19] Institute of Hydrology (2004), *Institute of Hydrology, report number 124, Flood Estimation for Small Catchments.*
[20] Environment Agency. Reservoir inundation mapping. http://www.environment-agency.gov.uk/homeandleisure/37837.aspx. Accessed September 2013.

3 Design criteria

3.1 Principal design criteria

3.1.1 The Proposed Scheme will provide a safe and reliable high speed rail link which will be compatible with the existing rail network and also HS1.

3.1.2 The railway will only provide a 'passenger' only service. The railway will not provide 'freight' operation.

3.1.3 The design shall seek to ensure that any impacts as a result of its development will be designed out or minimised as far as practicably possible.

3.2 Flood risk design approach statement

3.2.1 The overall project seeks to ensure that there is no increase in flood risk to any existing receptors as a result of the Proposed Scheme. This will be achieved by ensuring that overall flood storage capacity is maintained including an allowance for climate change.

3.2.2 In line with the NPPF technical guidance, increases in peak rainfall intensity and peak river flow of 20%, as a result of climate change, have been allowed for as per the period 2085 to 2115. This 20% increase has been used for the purposes of assessing flood risk. However, the hydraulic modelling involves sensitivity testing which includes a 20% increase, in addition to the 20% allowance for climate change.

3.2.3 All underbridge and viaduct crossings will be designed such that the 1 in 100 (1%) annual probability flow (with allowance for climate change) can pass underneath. Upstream water levels will not be increased and a minimum of 600mm freeboard will be provided to the bridge soffits above this level which will allow for debris to pass should flooding occur. On main rivers, where possible, a freeboard of 1m has been allowed.

3.2.4 Main River underbridges and viaducts will also accommodate river maintenance requirements and allow for a 5.3m vertical clearance above the floodplain ground level.

3.2.5 Culverts have been designed to convey the 1 in 100 (1%) annual probability flow (with allowance for climate change), with a freeboard of 300mm as a minimum applied for the culvert design. The design has also taken into account submerged inverts and the inclusion of mammal ledges.

3.2.6 River crossings will minimise any requirement for replacement floodplain storage areas.

3.2.7 The proposed rail infrastructure will be protected against inundation in the 1 in 1000 (0.1%) annual probability flood event. This will be achieved through ensuring a freeboard of 1m on the 1 in 1000 (0.1%) annual probability flood level. The railway drainage will be designed to have capacity up to the 1 in 100 (1%) annual probability peak rainfall event. However the design will also ensure that the flood level does not exceed 1m below the track level during the 1 in 1000 (0.1%) annual probability rainfall event.

3.2.8 All drainage will be attenuated in order that peak surface water run-off from the proposed infrastructure is no greater than the existing current day baseline run-off under the 1 in 100 (1%) annual probability peak rainfall event.

3.2.9 All drainage will be designed to ensure that disruption to existing groundwater flood flows will be kept to a minimum, both during and following construction of the permanent works.

3.3 Cross drainage design approach statement

3.3.1 The drainage design will ensure that there is no increase in run-off to the receiving watercourse as a result of the Proposed Scheme.

3.3.2 Surface and ground water drainage shall be provided so as to ensure that water levels do not rise above a 1m freeboard below the rail level.

3.3.3 The route will be designed to ensure safe operation of trains during a 1 in 1000 (0.1%) annual probability event.

3.3.4 As part of the drainage design an allowance of 30% has been added to design events for climate change.

4 Data sources

4.1.1 Consistent with the requirements of the NPPF, this assessment considers the risk of flooding from rivers, overland flow (surface water), rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The route will lie entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are:

- OS 1:10,000 mapping;
- topographic survey commissioned for the purposes of the Proposed Scheme (200mm grid resolution LiDAR survey, in digital terrain model and digital surface model format);
- Environment Agency Flood Zone mapping and historic flood mapping;
- the Environment Agency website for reservoir inundation mapping;
- the Warwickshire SFRA[10];
- the Warwickshire PFRA[11];
- Environment Agency national surface water flood mapping datasets, specifically the Midlands FMfSW; and
- Severn Trent Water asset mapping.

4.1.4 A high-level review of the risk of flooding and potential impacts has been undertaken on the basis of these datasets across all flood sources. Where this review indicated potentially significant impacts on the risk of flooding, or a risk of flooding to the line, further investigation has been undertaken, specifically hydraulic modelling for areas at risk from river flooding.

5 The Proposed Scheme

5.1 Permanent works

5.1.1 The general design of the Proposed Scheme is described in Volume 2, Section 2.2. The following section describes the main features of the Proposed Scheme in this study area, including the main flood risk mitigation measures.

Start of the Stoneleigh, Kenilworth and Burton Green CFA to Stoneleigh Business Park

5.1.2 On leaving the Offchurch and Cubbington area (CFA17), the route will enter the area in the south (Volume 2: Map Book, Map CT-06-093) in cutting. It will continue mainly in either cutting or partially retained cutting for approximately 2.9km, passing under the A445 Leicester Lane to the east of Stonehouse Farm (Map CT-06-093, F5), under the B4113 Stoneleigh Road (Map CT-06-094, G4) and through Stoneleigh Business Park.

5.1.3 Key features of this section of the route will include (from map CT-06-093, A5; to CT-06-094, A5):

- a 400m long shallow cutting with an average depth of approximately 2m, with raised earthworks on both sides to provide visual screening;
- a 200m long embankment with a height of up to 2m, with raised earthworks on both sides to provide visual screening;
- a 500m long cutting increasing in depth northwards up to approximately 10m, with raised earthworks on both sides of the southern part to provide visual screening;
- a 1.6km long retaining wall within a cutting south of and through most of Stoneleigh Business Park to reduce land take, provide noise screening, and prevent groundwater ingress from the River Avon;
- a 200m long cutting reducing in depth to the north (map CT-06-094, B6);
- two ponds for railway and highway drainage will be provided on the east side of the route, together with a pumping station immediately to the east of the Proposed Scheme, just south of Stareton[21]; and
- a replacement floodplain storage area will be constructed adjacent to the ecological mitigation area to provide additional flood storage.

Stoneleigh Business Park to River Avon viaduct

5.1.4 The route will then come out of cutting for about 350m to cross the River Avon immediately to the north of Stoneleigh Business Park. Key features of this section of the route (from Map CT-06-094, A5; to CT-06-095, H5 and I5) will include:

- a 130m long embankment increasing in height to the north;

[21] Railway drainage will generally be gravity driven, but where track levels required it, pumping stations will be utilised.

- an 80m long viaduct over the River Avon;
- a 150m long embankment decreasing in height to the north; and
- a railway drainage pond on the west side of the route immediately north of the River Avon.

River Avon Viaduct to Finham Brook Viaduct

5.1.5 The route will continue into cutting for approximately 1.3km, passing beneath the B4115 Ashow Road, the A46 Kenilworth Bypass and Dalehouse Lane to the east of Kenilworth Golf Club.

5.1.6 Key features of this section of the route (from Map CT-06-095,B6 to CT-06-095, H5) will include:

- a 1.3km long cutting, increasing in depth to approximately 14m towards the northern end, at which point the width of the cutting will be approximately 100m; localised mitigation earthworks will be provided adjacent to Dalehouse Lane to provide screening to properties and the golf course; and
- use of strengthened earthworks and retaining walls along Dalehouse Lane to minimise the footprint of the embankments where reasonably practicable within the floodplain and avoid land being required for construction and operation at the golf course.

Finham Brook viaduct to Canley Brook viaduct

5.1.7 The route will continue in a north-westerly direction, over the Finham Brook on viaduct before entering a 1.7km length of cutting, passing to the east of Kenilworth, under the existing Coventry to Leamington Spa Line and the A429 Kenilworth Road, and over the realigned Canley Brook.

5.1.8 Key features of this next section of the route (from Map CT-06-095, A6; to CT-06-097, G6) will include:

- a 60m long approach embankment on the south side of Finham Brook, approximately 5m high;
- a 60m long viaduct over the Finham Brook (Map CT-06-095, A6);
- an 80m long approach embankment on the north side of Finham Brook, approximately 6m high;
- a 1.7km long cutting varying in depth up to approximately 10m just north of the Coventry to Leamington Spa Line (Map CT-06-096, D5), and a width of up to 80m, with raised earthworks on both sides to provide visual and noise screening;
- a 1.35km long retaining wall within the above cutting to prevent groundwater ingress into the cutting;
- diversion of the Canley Brook to the west to cross beneath the railway about 600m north-west of its current location (Map CT-06-097, H5);
- a 50m long viaduct over the diverted Canley Brook;

- a 230m long cutting decreasing in depth from approximately 6m to ground level; and
- provision of two new railway drainage ponds to the east of the Proposed Scheme, one adjacent to the pumping station, and one just north of the realigned Canley Brook.
- a replacement floodplain storage area on the west side of the Proposed Scheme, near Dalehouse Lane, to provide potential additional flood storage to offset any impacts from the Proposed Scheme.

Canley Brook viaduct to Burton Green green tunnel

5.1.9 This 2.9km section of route will continue in a north-westerly direction, alternating between embankment and cutting as it passes between Crackley Wood to the west and Roughknowles Wood (Map CT-06-097) to the east. It will then pass to the west of South Hurst Farm and gradually converge with the alignment of the dismantled Kenilworth to Balsall Line, now known as the Kenilworth Greenway, where it will enter into tunnel just to the south of Burton Green.

5.1.10 Key features of this section of the route (from Map CT-06-097, G5; to CT-06-098, B4 and B5) will include:

- a 170m long embankment up to 2.5m high, with a culvert provided to carry an existing watercourse under the new embankment in Crackley Wood (Map CT-06-097, F6);
- an 800m long cutting with a depth of approximately 12m and a width of approximately 90m;
- a 1.2km long embankment, varying in height up to 8m with raised earthworks on both sides where the route is not in existing woodland to provide visual and noise screening;
- a 350m long cutting up to 3m deep with raised earthworks on both sides to provide visual screening;
- a 90m long embankment approximately 2m high with raised earthworks on the both sides to provide visual and noise screening;
- a new culvert to carry an unnamed stream below the route in Black Waste Wood (Map CT-06-098, G6); and
- provision of a railway drainage pond to the east of the Proposed Scheme, north of the Footpath 168 underpass.

Burton Green green tunnel to Waste Lane

5.1.11 On entering the proposed green tunnel, the route will continue in a north-westerly direction, passing through Burton Green tunnel before exiting just north of the village into retained cutting. It will then pass under the B4101 Waste Lane.

5.1.12 Key features of this section of the route (from Map CT-06-099, H5; to CT-06-100, E5) will include:

- a 621m long green tunnel, incorporating a 100m porous portal at each end (Map CT-06-099, E5, F5 G5 and H5);
- a 1.1km long retained cutting on the west side, and a combination of retained cutting and natural cutting on the east side, up to 12m deep, as shown on Maps CT-06-099 and CT-06-100; and
- a 140m length of low embankment (approximately 2m high).

5.1.13 The route will then continue north on low embankment, leaving the Stoneleigh, Kenilworth and Burton Green area and passing into the Balsall Common and Hampton in Arden area (CFA23).

5.2 Temporary works

5.2.1 All contractors will be required to comply with the environmental management regime for the Proposed Scheme, which will include:

- Code of Construction Practice (CoCP); and
- Local Environmental Management Plans (LEMPs).

5.2.2 The key requirements of the draft CoCP in relation to flood risk are:

- making appropriate use of the Environment Agency's flood warning service;
- preparing site specific flood risk management plans for temporary works at risk of flooding from river, surface water and groundwater sources;
- considering flood risk when planning temporary sites and storing materials;
- obtaining consent, as required, for works affecting a watercourse;
- removing or stopping and sealing of drains and sewers taken out of use;
- no discharge of site run-off to ditches, watercourses, drains or soakaways without agreement of the appropriate authority;
- hoarding and fencing in areas at risk of flooding will be permeable to floodwater, unless otherwise agreed with the Environment Agency or Local Lead Flood Authority; and
- precautions to be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

5.2.3 The temporary works will include both main and satellite construction compounds. These compounds will be utilised for office accommodation, local storage for plant and materials, car parking, material processing facilities and welfare facilities.

5.2.4 Areas adjacent to these compounds may be used for temporary storage of any topsoil stripped as part of the works.

5.2.5 Temporary worker accommodation will also be required for the Proposed Scheme.

6 Existing flood risk

6.1.1 One recorded incident of flooding in the vicinity of the route has been identified in this study area from the available data sources. This event caused inundation at and 900m upstream of the River Avon viaduct crossing at Stoneleigh Park. The extent of the Environment Agency historic flood map at this location is shown on WR-01-030, F6, (Volume 5, CFA18, Map Book).

6.1.2 The Warwickshire SFRA[10] indicates three recorded incidents of flooding at and in the vicinity of the route in this study area. The first caused inundation approximately 900m south of the River Avon viaduct crossing at Stoneleigh Park. The second caused inundation approximately 700m to the east of the route at Stoneleigh. The sources of both these flood events are unknown. The third incident occurred approximately 700m south of the route at Burton Green. This event was identified as surface water flooding. Apart from these three events, there are no other incidents of historical flooding within 1km from the route within this study area.

6.1.3 The Warwickshire PFRA[11] has also been used to identify potential locations of flooding in the vicinity of the route, and shows one incident of historical flooding at the location of the route centre line, located adjacent to the route on the River Avon at Stoneleigh Park. Owing to the location of the event, it is likely to be the same incident as recorded on the Environment Agency historical flood maps (i.e. 900m upstream of the River Avon from the River Avon viaduct crossing). The PFRA mapping also indicates that an incident of historical flooding occurred to the north of Kenilworth, within 1km from the route centre line.

6.2 River flooding

6.2.1 River flood risk is the risk of flooding posed by rivers and streams. The risk in CFA18 is from the River Avon, Finham Brook, and Canley Brook and its tributaries. The areas at risk of flooding from this source are shown in maps Volume 5 WR-05 and WR-06.

6.2.2 The assessment of baseline (current) flood risk involved identifying watercourse crossings and the associated risk through the use of the Flood Zones. The results of this assessment are provided in Table 2. The watercourse identifier references have been taken from Volume 5: Map Book – Water resources, maps WR-01-030 and WR-01-031.

Table 2: Stoneleigh, Kenilworth and Burton Green river flood risk

Watercourse identifier and map reference	Crossing name	Watercourse	1 in 100 (1%) + climate change Flow	Risk level	Receptor vulnerability
SWC-CFA18-001 Volume 5: Map Book – Water resources, Map WR-01-030, E5	River Avon viaduct	Main River (River Avon)	141.94m^3/s	Very high	Less vulnerable
SWC-CFA18-002 Volume 5: Map Book – Water resources, Map WR-01-030, C5	Finham Brook viaduct	Main River (Finham Brook)	15.53m^3/s	Very high	More vulnerable

Watercourse identifier and map reference	Crossing name	Watercourse	1 in 100 (1%) + climate change Flow	Risk level	Receptor vulnerability
SWC-CFA18-003 Volume 5: Map Book – Water resources, Map WR-01-031, H5	Canley Brook viaduct	Main River (Canley Brook)	13.88m^3/s	Very high	Less vulnerable
SWC-CFA18-004 Volume 5: Map Book – Water resources, Map WR-01-031, G5	Crackley Wood culvert	Ordinary watercourse (tributary of Canley Brook)	0.60m^3/s	Very high	Less vulnerable
SWC-CFA18-006 Volume 5: Map Book – Water resources, Map WR-01-031, E6	Broadwells Wood culvert	Ordinary watercourse (tributary of Canley Brook)	0.35m^3/s	Very high	Less vulnerable
SWC-CFA18-007 Volume 5: Map Book – Water resources, Map WR-01-031, D6	Black Waste Wood culvert	Ordinary watercourse (tributary of Canley Brook)	0.23m^3/s	Very high	More vulnerable

6.2.3 The Environment Agency Flood Mapping indicates four main areas at risk from river flooding in this study area. These are at the River Avon viaduct crossing, an area of the River Avon floodplain alongside the route, Finham Brook viaduct crossing and Canley Brook viaduct crossing. The Environment Agency flood mapping covers watercourses with catchments greater than 0.5km^2 and hence there are no identified Flood Zones for the culvert crossings of the three tributaries of Canley Brook. Table 2 shows the map references associated with these areas.

6.2.4 Hydraulic modelling as detailed in Section 2.6 was carried out to provide a more accurate representation of river flood risk along the route, specifically at locations where the route would cross a watercourse. The modelling provided flood extents for the 1 in 100 (1%) annual probability event with a 20% allowance for climate change and for the 1 in 20 (5%) annual probability event. Flood levels were also determined for the 1 in 1000 (0.1%) annual probability event to ensure that the proposed track will not be at risk during this event. The flood extents and levels as determined through hydraulic modelling are further detailed in the river modelling report (Volume 5, WR-004-011).

6.2.5 The hydraulic modelling redefines the Flood Zones at the location of the proposed River Avon viaduct, Finham Brook viaduct and Canley Brook viaduct (Volume 5: Map Book – Water resources, Map WR-05-048). Therefore the watercourses crossed by these respective viaducts are identified to be within Flood Zone 3b and hence classed as at a very high risk in line with Table 1. It was necessary to remodel the flooding extents of these watercourses to provide a more accurate extent of the river flood risk posed to the route. The hydraulic modelling also redefines the Flood Zones upstream of the River Avon crossing, where an area of landscaping that forms part of the Proposed Scheme lies within the Environment Agency Flood Zone 3. The hydraulic modelling shows that area is outside the refined Flood Zone 3 and Flood Zone 2, and so no further assessment was therefore necessary at this location.

6.2.6 The hydraulic modelling for the Crackley Wood culvert, Broadwells Wood culvert and Black Waste Wood culvert, indicates that these culverts will be located in areas categorised as being at a very high risk of river flooding.

6.2.7 The vulnerability classification provided in Table 2 is based on the NPPF and relates to the vulnerability of existing development at risk of river flooding. In line with the NPPF, a less vulnerable classification has been given for four out of the six watercourse crossings, because the land at risk in these areas is utilised for agricultural purposes (land and buildings used for agriculture and forestry). A more vulnerable classification has been assigned to the Finham Brook viaduct crossing, because residential properties are located adjacent to the Finham Brook both upstream and downstream of this crossing. A more vulnerable classification has been assigned to the Black Waste Wood culvert crossing, because residential properties are located adjacent to the tributary of Canley Brook upstream of the crossing.

6.2.8 The other locations along the route, not identified in Table 2, are considered to be at either a low risk or no risk of river flooding.

6.3 Surface water/overland flow

6.3.1 This section is an examination of the existing flood risk posed by rainfall falling on the ground surface, referred to as surface water flooding. It is examined in terms of the water flowing over the ground surface that has not entered a natural drainage channel or artificial drainage system.

6.3.2 The areas at risk from surface water flooding are shown on maps WR-01-030 and WR-01-031 (Volume 5: Map Book – Water resources). Table 3 details the risk to the development from this source of flooding.

Table 3: Stoneleigh, Kenilworth and Burton Green sources of surface water flooding

Description of surface water flooding location and map reference	Description of possible influence to the Proposed Scheme	Risk
Areas surrounding the Leicester Lane road crossing, south of Stonehouse Farm (Volume 5: Map Book – Water resources, Map WR-01-030, G6)	The route will cross an area susceptible to surface water flooding which is not associated with a watercourse. This area at risk is primarily at a low and medium risk, although areas adjacent to the western side of the track are located at a high risk.	High
The area between the west of Stareton and the east of the Kenilworth bypass, including Stoneleigh Park (Volume 5: Map Book – Water resources, Map WR-01-030, E5)	The route will cross an area susceptible to surface water flooding at the location of the River Avon viaduct crossing, categorised as being at a high risk. Also at this location the route will run parallel to two areas susceptible to surface water flooding that cross the B4115 on both sides of the Proposed Scheme. These areas are categorised as being at a medium and high risk. One further area susceptible will run parallel to the east of route, following the route of the River Avon, and is categorised as being at a high risk.	High

Description of surface water flooding location and map reference	Description of possible influence to the Proposed Scheme	Risk
The area between the west of the Kenilworth bypass and east of the A429 at Crackley (Volume 5: Map Book – Water resources, Map WR-01-030, C5 & D5)	The route will run adjacent to two areas susceptible to surface water flooding north and south of the route, located parallel to the west side of the Kenilworth bypass. These areas are not associated with a watercourse and are classified as being at a high risk. The route will also cross an area susceptible to surface water flooding at the location of the Finham Brook viaduct crossing, categorised as being at a high risk. There are two further areas susceptible to surface water flooding that will cross the route, which are located immediately east and west of Millburn Grange. Both these areas are categorised as being at a medium risk.	High
The area between the west of the A429 at Crackley and east of Crackley lane at Roughknowles Wood (Volume 5: Map Book – Water resources, Map WR-01-030, A5 & B5)	The route will cross two areas susceptible to surface water flooding, the first at the location of the Canley Brook viaduct crossing and the second at the location of the Crackley Wood culvert crossing. Both these areas are classified as being at a high risk.	High
The area from Broadwells Wood to Black Waste Wood (Volume 5: Map Book – Water resources, Map WR-01-031, E6)	An area susceptible to surface water flooding will be crossed the route immediately west of Broadwellls Wood culvert crossing. The flow path does not follow the route of the watercourse at this location and this area is classified as being at a high risk. There are also areas susceptible to surface water flooding to the north of the route that are associated with a drain that flows west to east from Black Waste Wood to Broadwells Wood. These areas are classified as being at a high risk.	High
The area between Little Poors Wood and Little Beanit Farm (Volume 5: Map Book – Water resources, Map WR-01-031, C5)	An area susceptible to surface water flooding will be crossed by the route and to the north of the route, located to the east of Beanit Spinney. This area is not associated with a watercourse and is classified as being at a medium risk.	Medium

6.3.3 There are six locations along the route in this study area which have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. At the majority of these locations the risk of surface water flooding ranges from low to high, however as a conservative approach the highest level of risk has been assigned. Therefore at five locations the risk is considered high and at one location the risk is considered medium.

6.3.4 In line with the risk category matrix provided in Table 1, and the data available for this FRA, all other locations along the route within this study area are classed to be at no risk from surface water flooding.

6.4 Groundwater

6.4.1 Groundwater flood risk has been qualitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions at the location of the Proposed Scheme. The assessment of the current groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth of groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

6.4.2 The SFRA[10] and PFRA[11] for the area do not record and particular areas of substantiated groundwater flooding. Therefore it is concluded that the risk from groundwater flooding is low.

6.5 Sewer systems

6.5.1 The risk to the route from the drainage and sewer network has been determined based on the location of development in relation to the network and the proximity and potential flow paths from inspection covers. Flow paths have been assessed through the use of LiDAR and OS mapping. A summary of this assessment is included in Table 4.

Table 4: Stoneleigh, Kenilworth and Burton Green sources of water and sewer network flooding

Source	Location[22]	Supplier	Comment	Risk
Sewer	CT-06-099, G6, F6	Severn Trent Water	The route will cross the sewer network twice, and there are inspection covers located at 20m and 30m from the route. At this location however the route is tunnelled.	Low
Sewer	CT-06-095, I6	Severn Trent Water	The route will cross the sewer network once; however there are no identified flow paths.	Low

6.5.2 Due to the nature of the closed sewer system, sewer flooding will only be caused if there is a blockage or a leak or if there is a rainfall event greater than the design capacity of the network.

6.5.3 There are two locations in this study area where the route will cross the sewer network, and inspection covers are located in the vicinity of the route. However at these locations the route is within a tunnel and hence there are no flow paths between this surcharge point and the Proposed Scheme.

6.6 Artificial sources

6.6.1 Artificial sources of flood risk describe a mechanism whereby flooding would be the result of failure of infrastructure that impounds water such as in a canal or reservoir.

6.6.2 The Proposed Scheme neither crosses nor is in close proximity to any canals in this study area, hence there is no risk from this source of flooding.

6.6.3 The Environment Agency reservoir inundation maps indicate that should Naseby Reservoir, Sulby Reservoir, Stanford Reservoir or Park Farm Reservoir fail, flood water will flow in a south westerly direction along the River Avon and pose a risk to the Proposed Scheme alongside the River Avon 900m from the River Avon viaduct crossing (map WR-01-030, F6, Volume 5, CFA18, Map Book). These reservoirs are located in excess of 2km upstream of the area at risk. At this location the extents of flooding shown on the reservoir inundation maps cover slightly larger extents than the areas at risk from river flooding. However the upstream land use is categorised as less vulnerable and hence if the Proposed Scheme acts as a constriction to flow at this location, no existing vulnerable receptors would be at an increased risk of flooding from this source.

[22] See Volume 2: Map Book for locations.

6.6.4 The Environment Agency reservoir inundation maps also indicate that the Proposed Scheme would also be at risk at the location of the River Avon viaduct (map WR-01-030, E5, Volume 5, CFA18, Map Book) should Naseby Reservoir, Coombe Pool Reservoir, Stanford Reservoir or Park Farm Reservoir fail. The width of the inundation at this location is less than the width of Flood Zones 2 and 3 which has been shown not to affect the route.

6.6.5 Due to the strict regulations and high maintenance associated with reservoirs the risk of breaching is considered unlikely. In line with the risk category matrix in Table 1 the risk of flooding from this source is considered low.

6.7 Summary

6.7.1 The Proposed Scheme will cross six watercourses and therefore it is concluded that the Proposed Scheme will be within areas that are classified as being potentially at a very high risk from river flooding. The land uses at risk in this study area (which could be impacted as result of the Proposed Scheme) are classed as less vulnerable for four of the watercourse crossings. Near the Finham Brook viaduct and Black Waste Wood culvert residential properties are present and hence a more vulnerable classification has been assigned.

6.7.2 There are six locations along the route which have been identified to be at risk from surface water flooding. The risk at these locations generally ranges from low to high, although as a conservative approach the highest level of risk has been assigned. Therefore five locations have been categorised as being at a high risk and one location at a medium risk.

6.7.3 The risk of groundwater flooding has been assessed as low as no substantiated instances of groundwater flooding have been reported.

6.7.4 Even though the Proposed Scheme will cross, or be located in close proximity to the sewer systems twice, there are no known flow paths of flooding to the Proposed Scheme. As a result the flood risk from this source is considered low.

6.7.5 There will be no risk to the Proposed Scheme from canal flooding. Due to the strict monitoring and maintenance requirements, the risk of reservoir flooding to the development is considered low.

7 Flood risk management measures

7.1 River flood risk

Flood risk to Proposed Scheme

7.1.1 The Proposed Scheme has been raised above floodplain crossings such that the risk of river flooding is less than during the 1 in 1000 (0.1%) annual probability. Therefore the mitigation measures included in the design have ensured that there are no instances where the Proposed Scheme would be at significant risk of river flooding, and consequently no specific mitigation is required.

Impact of Proposed Scheme

7.1.2 At all floodplain crossings, replacement floodplain storage would be provided upstream of the Proposed Scheme for losses in floodplain storage, including viaduct piers, embankments and all associated development.

River Avon viaduct

7.1.3 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 21mm, extending to a maximum distance of 1,077m upstream of the River Avon viaduct during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. This change in flood level causes a minor impact. This minor impact would be reduced through the incorporation of replacement floodplain storage, which is proposed upstream of the viaduct.

Finham Brook viaduct

7.1.4 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 12mm, extending to a maximum distance of 20m upstream of the Finham Brook viaduct during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. This change in flood level causes a minor impact. Although a minor impact is expected, a replacement floodplain storage area has been identified which will be incorporated if necessary.

Canley Brook viaduct

7.1.5 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 133mm, extending to a maximum distance of 400m upstream of the Canley Brook Viaduct during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. This change in flood level causes a major impact immediately upstream of the Proposed Scheme. However, the flood extent in the vicinity of Cryfield Grange Road shows increases of only up to 1mm, which is a negligible impact. The final detailed design of this crossing is yet to be confirmed, and replacement flood storage will be incorporated where necessary in order to reduce any residual impact.

Crackley Wood culvert

7.1.6 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 21mm, extending to a maximum distance of 13m upstream of the Crackley Wood culvert during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. This change in flood level causes a minor impact. This

minor impact would be reduced through the incorporation of replacement floodplain storage, which is proposed upstream of the culvert.

Broadwells Wood culvert

7.1.7 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to 81mm, extending to a maximum distance of 6m upstream of the Broadwells Wood culvert during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. Given that this change in flood level is limited to 6m upstream of the crossing, the culvert causes a negligible impact. Given the negligible impact assigned at this location mitigation is not deemed necessary.

Black Waste Wood culvert

7.1.8 Hydraulic modelling at this location suggests that the Proposed Scheme will result in an afflux of up to -9mm at the Black Waste Wood culvert, during the 1 in 100 (1%) annual probability event with a 20% allowance for climate change. This change in flood level causes a negligible impact. Given the negligible impact assigned at this location mitigation is not deemed necessary.

Mitigation for temporary works

7.1.9 The temporary works have the potential to result in an increased river flood risk and be at risk of flooding from this source. The proposed mitigation and measures to prevent an unacceptable risk of river flooding for the temporary works includes signing up to the Environment Agency flood warning system for the "Middle Avon Rugby to Bideford – Low-lying land and roads between Rugby and Bideford including caravan parks and farmland" and also the "River Leam and River Itchen – Low-lying land and roads between Grandborough and Leamington, including Long Itchington". Any temporary crossings will be designed to prevent an increased flood risk through ensuring sufficient capacity during the 1 in 100 (1%) annual probability event; an indication of the flows which will be considered are included in Table 2.

7.2 Surface water flood risk

Flood risk to Proposed Scheme

7.2.1 In this study area, the areas categorised as being at a high risk of surface water flooding are generally associated with the six watercourses identified in the river flooding sections in this report. At these locations the scheme design will ensure that the track is situated above the 1 in 1000 (0.1%) annual probability event flood level with a 1m freeboard. Therefore as long as there is no blockage of these structures, a low surface water flood risk to the track is anticipated at these locations.

7.2.2 At the other locations where the route potentially crosses surface water flow paths, the track will either be raised on an embankment and/or the track drainage system will direct surface water flow away from the Proposed Scheme. Therefore, as long as the collection systems and surface water culverts are designed with sufficient capacity, there should be no backing up, and no expected risk of flooding to the Proposed Scheme.

Impact of Proposed Scheme

7.2.3 Potential increases in peak discharge rates of surface water run-off will be attenuated prior to discharging to the receiving watercourse. Any additional surface water to be discharged will be at a trickle rate to prevent exceeding the current capacity of the receiving watercourse.

7.3 Risk of flooding from groundwater

Flood risk to Proposed Scheme

7.3.1 The risk from groundwater flooding to the Proposed Scheme has been assessed as low and therefore no specific management measures are considered necessary.

Impact of the Proposed Scheme

7.3.2 The Proposed Scheme is not anticipated to have an impact on groundwater flooding and therefore no specific management is considered necessary.

7.4 Risk of flooding from drainage systems

7.4.1 There will be a low risk of flooding from drainage systems to the Proposed Scheme, and there will be no anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific mitigation would be required.

7.5 Risk of flooding from artificial sources

Flood risk to Proposed Scheme

7.5.1 There are no instances where the Proposed Scheme would be at significant risk of flooding from artificial sources, and consequently no specific mitigation is required.

Impact of the Proposed Scheme

7.5.2 Although the Proposed Scheme is at risk of flooding resulting from the complete failure of upstream reservoirs, the replacement floodplain storage provided to mitigate the potential effects of the River Avon viaduct would serve to either fully or partially offset any potential effects of the Proposed Scheme on flooding from this source at the location of the River Avon viaduct crossing. Due to the low probability of such flooding occurring, and the likely low significance of any impacts arising from the Proposed Scheme, it is not considered appropriate to provide additional mitigation for this scenario.

8 Post-development flood risk assessment

8.1 River flooding

8.1.1 The key design elements of the route for the Proposed Scheme with potential flood risk considerations have been modelled for this FRA. The modelling methodology and results specific for each watercourse crossing are included in the modelling report (Volume 5, WR-004-011). A summary of the results are presented in Table 5. The watercourse identifier references have been taken from WR-01-047 to WR-01-050 (Volume 5: Map Book – Water resources).

Table 5: Stoneleigh, Kenilworth and Burton Green river flood risk

Watercourse identifier and map reference	**Crossing name**	**1 in 100 (1%) climate change flow**	**Change in flood level 1 in 100 (1%) climate change**	**Change in flood level 1 in 1000 (0.1%)**	**Proposed Scheme 1 in 1000 (0.1%) level**	**Length of impacted upstream reach[23]**
SWC-CFA18-001 Volume 5: Map Book – Water resources, Map WR-05-048, I6(	River Avon viaduct	141.94m3/s	21mm	66mm	56.495m AOD	1,077m
SWC-CFA18-002 Volume 5: Map Book – Water resources, Map WR-05-048, E6	Finham Brook viaduct	15.53m^3/s	15mm	24mm	66.380m AOD	21m
SWC-CFA18-003 Volume 5: Map Book – Water resources, Map WR-05-049, H6	Canley Brook viaduct	13.88m^3/s	133mm	139mm	71.833m AOD	400m
SWC-CFA18-004 Volume 5: Map Book – Water resources, Map WR-05-049, G6	Crackley Wood culvert	0.60m^3/s	21mm	79mm	76.872m AOD	13m
SWC-CFA18-006 WR-05-049, D7	Broadwells Wood culvert	0.35m^3/s	81mm	139mm	91.018m AOD	6m
SWC-CFA18-007 WR-05-049, A7	Black Waste Wood culvert	0.23	-9	5	112.622	0

8.1.2 The hydraulic modelling at the Finham Brook viaduct, Broadwells Wood culvert and Black Waste Wood culvert reveals that the Proposed Scheme will have a negligible impact on flood levels during the 1 in 100 (1%) with an allowance for climate change annual probability event.

[23] Length of reach upstream of the Proposed Scheme along which flood levels during the 1 in 100 (1%) annual probability with an allowance for climate change event are greater than 10mm.

8.1.3 The hydraulic modelling at the River Avon viaduct and the proposed Crackley Wood culvert reveals that the Proposed Scheme will have a minor impact on flood levels during the 1 in 100 (1%) with an allowance for climate change event.

8.1.4 The Proposed Scheme involves the realignment of the Canley Brook at the location of the Canley Brook viaduct. The realignment will divert the watercourse around the western viaduct abutment. The hydraulic modelling at this location incorporates the watercourse realignment. Currently the Proposed Scheme, both the viaduct and watercourse realignment combined, will have a major impact on flood levels. However the area in the vicinity of Cryfield Grange Road is showing a negligible impact on flood levels.

8.1.5 The Proposed Scheme involves the realignment of the tributary of Canley Brook downstream of the Crackley Wood culvert crossing. The realignment will divert the watercourse around a proposed bridleway and balancing pond, which includes two culvert crossings. These culverts have not been included in the hydraulic modelling, because the same design criteria used for Crackley Wood culvert should be used for these structures.

8.1.6 Watercourses pose a river flood risk to the other design elements in this study area. The areas at risk from river flooding are shown on maps WR-05-047 to WR-05-050 (Volume 5: Map Book – Water resources) which are based on the hydraulic modelling results rather than Environment Agency Flood Zone mapping. The river flood risks to these works are included in Table 6.

Table 6: Other design elements at risk from river flooding

Works at risk	Watercourse identifier and map reference	Location Description	Description of the works and flood risk	Risk
Highways Landscaping	SWC-CFA18-001 Volume 5: Map Book – Water resources, Map WR-05-047, C6	Proposed Scheme 900m south of the River Avon viaduct crossing	A proposed footpath will encroach into the areas at risk from river flooding. A surface water drain connecting a balancing pond with the River Avon will encroach onto the River Avon floodplain.	Very high
Highways	SWC-CFA18-004 Volume 5: Map Book – Water resources, Map WR-05-049, G6	Tributary of Canley Brook downstream of the Crackley Wood culvert crossing.	A proposed bridleway crosses an area at risk from river flooding, associated with a tributary of Canley Brook. Also a diverted bridleway is located alongside this watercourse.	Very high
Highways Landscaping	SWC-CFA18-006 Volume 5: Map Book – Water resources, Map WR-05-049, D7	Tributary of Canley Brook at the Broadwells Wood culvert crossing.	A proposed footpath will cross an area at risk from river flooding, associated with a tributary of Canley Brook. Also landscape earthworks cross this watercourse.	Very high

8.1.7 The proposed realignment of a tributary of Canley Brook (SWC-CFA18-004) will require the installation of two new watercourse culverts. However this will be downstream of the location of the Crackley Wood culvert crossing, which has been included in the hydraulic modelling, and showed a minor impact on peak flood levels. It is recommended that these the culverts are designed to convey the same flow as the Crackley Wood culvert upstream of these two proposed culverts. The land uses

both upstream and downstream of the two proposed culverts are classed as less vulnerable, and so any change in flood risk will be on less vulnerable development.

8.1.8 Temporary works as required for the construction phase are also located in areas at risk from river flooding. The areas at risk are shown on maps WR-05 and WR-06 (Volume 5, CFA18, Map Book) and are based on the hydraulic modelling results rather than Environment Agency Flood Zone mapping. The temporary works at risk are listed in Table 7.

Table 7: River flood risk to temporary works

Watercourse identifier and map reference	Receptor	Comment	Risk
SWC-CFA18-001 Volume 5: Map Book – Water resources, Map WR-05-047, C6	Proposed Scheme 900m south of the River Avon viaduct crossing	A temporary material stockpile is located within the floodplain of the River Avon 900m upstream of the River Avon viaduct crossing.	High
SWC-CFA18-002 Volume 5: Map Book – Water resources, Map WR-05-048, E6	Finham Brook viaduct	A temporary plant crossing over Finham Brook will be required, including a temporary culvert which will be located in the area at risk during the 1 in 20 (5%) annual probability event.	Very high

8.1.9 There are two locations of temporary works that are located in areas at risk from river flooding. The areas at risk have been identified through the hydraulic modelling completed for this assessment.

8.1.10 Hydraulic modelling is not considered necessary for the temporary works because the works will be constructed in line with the draft CoCP and thus the design will consider river flood risk. Therefore temporary works will not result in an increased flood risk to any existing receptors.

8.1.11 The hoarding and fencing around a site for security purposes has the potential to alter flow paths and thus impact on flood risk at the two locations identified in Table 7. However the draft CoCP states that hoarding and fencing in areas at risk of flooding will be permeable to floodwater, unless otherwise discussed with the Environment Agency or Local Lead Flood Authority. This will ensure that the floodplain continues to function effectively for storage and conveyance of floodwater.

8.1.12 The temporary works other than those outlined in Table 7 are considered to be at low risk of river flooding.

8.2 Surface water/overland flow

8.2.1 The proposed track will result in increased run-off rates due to a reduction in infiltration capacity. Therefore the entire length of the track may be at risk from this source and could increase risk elsewhere.

8.2.2 In addition the track drainage has the potential to increase flood risk in receiving watercourses if not attenuated. In this study area there are nine proposed balancing ponds, these are located as follows:

- three in the vicinity of the A445 Leicester Lane overbridge;
- two in the vicinity of the Stoneleigh Road overbridge;
- adjacent to the River Avon at the river Avon viaduct crossing;
- in the vicinity of the Kenilworth Road overbridge;
- adjacent to the Canley Brook realignment upstream of the Canley Brook viaduct crossing; and
- adjacent to Footpath W168 underpass.

8.2.3 The outfall from these balancing ponds will be attenuated to prevent an increase in risk.

8.2.4 The route has the potential to interrupt surface water movement, which could result in an increase in surface water flood risk.

8.2.5 To the north west of the proposed River Avon viaduct the FMfSW indicates two overland flow paths for surface water either side of the Proposed Scheme that cross the realignment of the B4115 and flow into the River Avon. Assuming surface water will flow in this direction, it is anticipated that the culverts included in the B4115 will be of sufficient capacity to convey these flows, and so the Proposed Scheme (particularly the track) will be at a low risk from this source of flooding. In addition, the interruption of surface water flow, as a result of the Proposed Scheme, at this location would not significantly impact on surface water flood risk elsewhere.

8.2.6 Two linear overland flow paths are evident on either side of the Proposed Scheme parallel to the Kenilworth Bypass. The southern overland flow path is not crossed by the Proposed Scheme. A small part of the overland flow path to the north encroaches onto the Proposed Scheme. Any flow to the north of the Proposed Scheme will discharge to the proposed swale/infiltration trench to be provided at the embankment toe. Therefore at this location, whether the Proposed Scheme will intercept surface water movement or not, surface water will be discharged to the Finham Brook without causing an increased risk elsewhere.

8.2.7 To the east and west of Millburn Grange there are two overland flow paths evident that will cross the Proposed Scheme. Any flow to the north of the Proposed Scheme, flowing south, will discharge to the proposed swale/infiltration trench to be provided at the embankment toe. Any surface water to the south of the Proposed Scheme at this location will flow south and away from the track, towards Canley Brook, ultimately flowing into Finham Brook. Therefore at this location, whether the Proposed Scheme will intercept surface water movement or not, surface water will be discharged to the Canley Brook and Finham Brook (as it does at present) without causing an increased risk elsewhere.

8.2.8 Immediately west of the Broadwells Wood culvert crossing an overland flow path is evident that will cross the Proposed Scheme. Any flow to the Proposed Scheme will discharge to the proposed swale/infiltration trench to be provided at the embankment toe. Therefore at this location, whether the Proposed Scheme will intercept surface water movement or not, surface water will be discharged to the receiving tributary of Canley Brook (SWC-CFA18-006) without causing an increased risk elsewhere.

8.2.9 The potential impact of the Proposed Scheme on surface water movement, not identified as above, will be incorporated within the scheme design. Therefore the works will have no impact on surface water flood risk.

8.2.10 There are various aspects of the other design elements which will be at risk from surface water flooding. The surface flood risks to the other design elements, as identified from the Environment Agency FMfSW are included in Table 8.

Table 8: Surface water flood risks to other design elements of the Proposed Scheme

Works at risk	Location description and map reference	Description of possible influence to the Proposed Scheme	Risk
Earthworks	Areas surrounding the Leicester Lane road crossing, south of Stonehouse Farm. Volume 5: Map Book – Water resources, Map WR-01-030, H6	Earthworks will cross an area susceptible to surface water flooding, categorised as being at a low and medium risk. This area is not associated with a watercourse.	Medium
Highways Landscaping	The area between the west of Stareton and the east of the Kenilworth bypass, including Stoneleigh Park. Volume 5: Map Book – Water resources, Map WR-01-030, E5 & F6	The proposed B4115 realignment will cross two areas susceptible to surface water flooding either side of the Proposed Scheme track. The area to the north is categorised as being at a medium risk and the area to the south is categorised as being at a high risk, both are not associated with watercourses. A surface water pipe also will cross an area susceptible to surface water flooding, categorised as being at a high risk.	High
Earthworks	The area between the west of the Kenilworth bypass and east of the A429 at Crackley. Volume 5: Map Book – Water resources, Map WR-01-030, C5 & D5	Two areas susceptible to surface water flooding will be crossed by earthworks, both categorised as being at a medium risk. These areas are not associated with a watercourse.	Medium
Highways Landscaping	The area between the west of the A429 at Crackley and east of Crackley lane at Roughknowles Wood. Volume 5: Map Book – Water resources, Map WR-01-030, A5	A diverted bridleway will cross into an area susceptible to surface water flooding, associated with a tributary of Canley Brook. This area is at a high risk. A balancing pond will also be located in an area susceptible to surface water flooding, associated with the same tributary of Canley Brook. This area is classified as being at a medium risk.	High
Earthworks	The area from Broadwells Wood to Black Waste Wood. Volume 5: Map Book – Water resources, Map WR-01-031, E5 & E6	An area susceptible to surface water flooding will be crossed by earthworks, immediately west of the Broadwells Wood culvert crossing. This area is categorised as being at a high risk.	High
Highways Landscaping Other	The area between Little Poors Wood and Little Beanit Farm. Volume 5: Map Book – Water resources, Map WR-01-031, C5	The Burton Green feeder station and autotransformer will encroach into an area susceptible to surface water flooding. This area is not associated with a watercourse and is categorised as being at a medium risk.	Medium

8.2.11 There are six locations where other design elements are located in areas susceptible to surface water flooding. In general these areas range from low to high risk and as a conservative approach the highest level of risk has been assigned. Therefore, three of

the six locations are categorised as being at a high risk, with the remaining three locations categorised as being at a medium risk of surface water flooding.

8.2.12 The other design elements not listed in Table 8 are considered to be at no risk from surface water flooding in line with the flood risk category matrix.

8.2.13 All other design elements, including those additional to Table 8, have the potential to increase surface water run-off rates through reduced infiltration capacity. The design for the Proposed Scheme includes surface water run-off management (such as drainage channels and balancing ponds) to prevent an increased risk of flooding from this source both on site and in neighbouring areas.

8.2.14 Table 9 details the risk to the temporary design elements from surface water flooding.

Table 9: Sources of surface water flooding to temporary works

Description of surface water flooding location and map reference	Description of possible influence on temporary design elements	Risk
River Avon viaduct crossing Volume 5: Map Book – Water resources, Map WR-01-030, E5 & E6	River Avon viaduct (north) compound is located in an area susceptible to surface water flooding. This area is not associated with a watercourse and is categorised as being at a medium risk. A material transfer stockpile is also located within the aforementioned area which is susceptible to surface water flooding, categorised as being at a low and medium risk.	Medium
Kenilworth Bypass Volume 5: Map Book – Water resources, Map WR-01-030, D5	A46 Kenilworth Bypass overbridge compound is located in an area susceptible to surface water flooding, not associated with a watercourse. This area is classified as being at a high risk.	High
Finham Brook viaduct crossing Volume 5: Map Book – Water resources, Map WR-01-030, C5	A temporary plant crossing, including a temporary culvert crossing, is in an area at risk of surface water flooding, associated with Finham Brook. This area is categorised as being at a low, medium and high risk.	High
West of Milburn Grange Volume 5: Map Book – Water resources, Map WR-01-031, H5	Coventry to Leamington Rail overbridge (south-west) compound is located in an area at risk of surface water flooding, not associated with a watercourse. This area is categorised as being at a low, medium and high risk.	High
East of Little Poors Wood Volume 5: Map Book – Water resources, Map WR-01-031, D6	A temporary cycle track crosses an area susceptible to surface water flooding, not associated with a watercourse. This area is categorised as being at a low risk.	Low

8.2.15 There are five locations of temporary design elements in this study area which have been identified to be at risk from surface water flooding from the Environment Agency FMfSW. A conservative approach has been taken in categorising risk as outlined earlier in this section. Therefore, in line with the flood risk category matrix (Table 1) a high risk of surface water flooding has been categorised at three locations, a medium risk at one location and a low risk at one location.

8.2.16 Main construction and satellite construction compounds have the potential to interrupt surface water flow paths. The River Avon viaduct (north) compound is located on the edge of a potential surface water flow path and although surface water flow may be slightly diverted, the overall flow path will not be altered and no vulnerable receptors would be at an increased risk. At the A46 Kenilworth Bypass overbridge compound and the Coventry to Leamington Rail overbridge (south-west) compound surface water flow paths are limited by the underlying topography and hence there will be no interruption of flow paths.

8.2.17 In line with the risk category matrix provided in Table 1, all other locations for temporary works within this study area are classed to be at no risk from surface water flooding.

8.2.18 The works will be completed in line with the CoCP and hence the design of the temporary works will prevent an unacceptable level of surface water flood risk on site.

8.2.19 Temporary works not identified to be at risk on the FMfSW also have the potential to increase flood risk from this source in neighbouring areas as a result of reduced ground permeability. Therefore, in line with the draft CoCP, surface water will be managed at all locations of temporary works, including areas not identified to be at risk from surface water in Table 9. This will ensure that the temporary works are at an acceptable level of risk and do not cause an increased risk elsewhere from surface water flooding.

8.3 Groundwater

8.3.1 Stoneleigh retaining wall runs approximately parallel to the River Avon and will be designed to be an impermeable retained cutting. This structure has the potential to interrupt groundwater flow which, it is assumed, is towards the river. This interruption has the potential to increase groundwater levels which could lead to groundwater flooding.

8.3.2 This risk will be assessed in more detail during the detailed design stage following ground investigation. If necessary, mitigation will be included by providing drainage on the up gradient side to ensure that groundwater levels do not rise to a level that creates an increased risk of flooding.

8.3.3 The CoCP will be adhered to and hence the Proposed Scheme will not result in an increased groundwater flood risk to the location of the works or in neighbouring areas.

8.4 Sewer Systems

8.4.1 There are two locations where the route would cross sewer systems. However the risk to the Proposed Scheme from this source of flooding is low. This is due to the location of the route in relation to inspection covers and that there are no known flow paths between surcharge points and the works. At the two locations where inspection covers were identified, the route is tunnelled and so there are no known flow paths to the Proposed Scheme. Once operational, it is not anticipated that the Proposed Scheme will impact on flood risk from this source. The most likely risk is considered to occur during the constructions phase and the draft CoCP will ensure a minimal risk from this source.

8.4.2 There are four locations in which the sewer network crosses temporary design elements, specifically vegetation clearance areas, demolition areas, a temporary road verge and temporary foundations. All these locations are considered to be at a low risk of flooding from the sewer network.

8.4.3 The works will be completed in line with the draft CoCP and hence will ensure that the Proposed Scheme and neighbouring areas will not be at an increased flood risk from this source. One such measure outlined in the draft CoCP requires the removal or stopping and sealing of drains and sewers taken out of use. Similarly as outlined in the draft CoCP, precautions will also be taken to prevent damage to services and to avoid pollution during service diversions, excavations and ground penetration.

8.5 Artificial Sources

8.5.1 At locations where the route crosses canals or areas at risk of flooding as a result of reservoir failure, there is potential that the Proposed Scheme may either increase the risk of flooding from this source, or divert flood water causing new areas to be put at risk.

Reservoirs

8.5.2 The Environment Agency reservoir inundation maps indicate that should Naseby Reservoir, Subly Reservoir, Stanford Reservoir, Park Farm Reservoir or Coombe Pool Reservoir fail, flood water would flow in a south-westerly direction along the River Avon and pose a flood risk to the Proposed Scheme at the Rive Avon viaduct. The other design elements located in the area at risk of reservoir inundation include the redirection of the sewer network and a surface water pipe. The temporary works identified within the reservoir inundation extent include a temporary material stockpile.

8.5.3 There are no other locations within this study area that are at risk of flooding from reservoir failure as shown on the Environment Agency reservoir inundation maps. It is therefore concluded that the Proposed Scheme, including the route, other design elements and temporary works, will be at a low risk of flooding from this source (Table 1) and will not result in an increased risk elsewhere.

Canals

8.5.4 There are no canals within this CFA.

8.6 Summary

8.6.1 The Proposed Scheme, including the route, other design elements and the temporary works are located in areas at a very high risk of flooding from rivers. The design will ensure that the track is located above the 1 in 1000 (0.1%) annual probability flood event, with a freeboard, and hence will be at an acceptable level of risk. The other design elements and temporary works will be completed in line the CoCP requirements and hence will also be at an acceptable level of risk. The hydraulic modelling completed for this assessment has shown that the Proposed Scheme will have a major impact on flood risk. However, the design will include mitigation to reduce this to a negligible impact.

8.6.2 All elements of the Proposed Scheme will cross many areas susceptible to surface water flooding. In general, at each of the areas the risk ranges from low to high, although as a conservative approach the highest level of risk has been assigned resulting in many of the areas being categorised as being at a high risk from surface water flooding. However, the Proposed Scheme will mitigate surface water run-off to ensure that the works are at an acceptable level of flood risk and do not result in an increased risk elsewhere.

8.6.3 The Proposed Scheme could, in the absence of mitigation, increase the risk of groundwater flooding in the vicinity of Stoneleigh retaining wall. However, this potential risk can be readily mitigated such that there is no significant increase in the risk of groundwater flooding.

8.6.4 All elements of the Proposed Scheme have been categorised as being at a low risk from the sewer network as there are no known flow paths between these sources of flood risk and the works. In addition the works will be completed in line with the draft CoCP and hence will prevent an increase in flood risk from this source.

8.6.5 There are no canals crossed or located in close proximity to the temporary design elements. Due to the strict monitoring and maintenance requirements, the risk of reservoir flooding to the development is considered low. The design ensures that the Proposed Scheme does not result in an increased risk from this source both to the development and elsewhere.

9 Conclusion

9.1.1 The Proposed Scheme, including the route, other design elements and the temporary works, are to be located within areas at risk from flooding from a range of sources. However, the temporary works will be designed to and will follow the draft CoCP such that development will be at an acceptable level of risk and will not cause an increased risk elsewhere. The proposed mitigation as part of the permanent works will also ensure that the Proposed Scheme will be at an acceptable level of flood risk and will not result in an increased risk elsewhere.

9.1.2 The magnitude of impact and significance of effects have been based on the Environmental Impact Assessment (EIA) Scope and Methodology Report (SMR), see Volume 5: Appendix CT-001-000/1. Table 10 shows a summary of the sources of flood risk within this study area and the associated magnitude of impact and significance of effects.

9.1.3 In terms of river flooding, the Proposed Scheme shows major changes in flood risk. However, only less vulnerable development (land used for agriculture and forestry) is affected by these major changes. In the vicinity of the Cryfield Grange Road where vulnerable receptors are located, a minor impact was identified. Further design and mitigation will also reduce this impact. Therefore taking this into account, the overall magnitude of impact in this study area of the Proposed Scheme with the floodplain replacement storage is negligible and significance of effects neutral.

9.1.4 Although there are areas of the Proposed Scheme at no, low, medium and high risk from surface water flooding, overall the risk from this source is categorised as high, as a conservative approach. However, the overall magnitude of impact is negligible and the significance is neutral. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 0 of this report and the temporary and construction works assessed as part of this FRA in line with the draft CoCP.

9.1.5 Although there is one area where the Proposed Scheme could increase groundwater flooding, mitigation will be included to prevent any significant increase in risk.

9.1.6 The risk from sewer flooding is low within this study area, and the overall magnitude is negligible with a neutral significance. This has been determined because the design of the permanent works will be in line with the design criteria outlined in Section 0 of this report and the temporary construction works in line with the draft CoCP.

9.1.7 There are no canals in this study area and hence no associated flood risk from this source. The risk of reservoir flooding is considered low in this study area resulting in a low significance of effect.

Table 10: Summary of flood risk receptors showing the overall magnitude of impact and significance of effects

Flood risk Receptor	Risk category	Magnitude of impact	Significance of effects
Areas at risk from river flooding	Very high	Negligible	Neutral
Areas at risk from surface water flooding	High	Negligible	Neutral
Areas at risk from groundwater flooding	Low	Negligible	Neutral

Flood risk Receptor	Risk category	Magnitude of impact	Significance of effects
Areas at risk from drainage and sewer flooding	Low	Negligible	Neutral
Areas at risk of flooding from artificial sources	Low	Negligible	Neutral

9.2 Residual flood risk to the Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from river sources

River Avon viaduct

9.2.2 There are no significant hydraulic structures within the vicinity of the Proposed Scheme that would create additional residual risks to the Proposed Scheme. The viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Finham Brook viaduct

9.2.3 There are no significant hydraulic structures within the vicinity of the Proposed Scheme that would create additional residual risks to the Proposed Scheme. The viaduct would be at a significant height above the floodplain, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Canley Brook viaduct

9.2.4 There is one existing hydraulic structure in the vicinity of the Canley Brook viaduct, the Crackley Bridge. The Crackley Bridge is located downstream of the Proposed Scheme and there is the potential that blockage at this structure would impact on flood levels at the location of the Proposed Scheme. However the viaduct is above the 1 in 1000 (0.1%) annual probability event peak flood level, and hence the residual risks of flooding over and above the design event, and the risk of blockage, would not be significant.

Crackley Wood culvert

9.2.5 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at minor watercourse crossings arising from potential blockage of culverts.

Broadwells Wood culvert

9.2.6 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at minor watercourse crossings arising from potential blockage of culverts.

Black Waste Wood culvert

9.2.7 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at minor watercourse crossings arising from potential blockage of culverts.

Residual flood risks from surface water sources and minor watercourses

9.2.8 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Therefore, there are not expected to be any significant increases in risk of flooding at dry valley crossings arising from potential blockage of culverts.

Residual flood risks from groundwater

9.2.9 Groundwater levels rise and fall relatively slowly, and therefore any change in the risk of flooding from this source would be the result of below ground intervention. The risk of groundwater flooding already considered in this FRA presents an absolute risk, and there are no significant residual risks arising from this source.

Residual flood risks from the sewer network

9.2.10 Blockage of underground sewer networks can cause surcharge and associated flooding. At locations where the existing sewer infrastructure will need diverting, any replacement infrastructure would be to at least the same standard as existing. Consequently, no additional residual risk to the Proposed Scheme would be expected as a result of drainage system failure.

Residual flood risks from artificial and surface sources

9.2.11 This assessment considers the potential for total failure of Naseby Reservoir, Subly Reservoir, Stanford Reservoir, Park Farm Reservoir and Coombe Pool Reservoir, which are deemed to be the most extreme cases of flooding from these sources. Therefore it is considered that there are no further residual risks from artificial sources of flood risk.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 All culverts within the Proposed Scheme will be designed to convey the 1 in 100 (1%) annual probability flow including an allowance for climate change with a minimum internal headroom of 300mm above the design flood water level (to minimise the risk of blockage). Consequently, there would be negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.3.2 All viaducts within the Proposed Scheme will also be designed such that the 1 in 100 (1%) annual probability flow with an allowance for climate change can pass underneath. As a minimum the design ensures that a 600mm freeboard will be provided to the bridge soffits above this level, and on main rivers where possible, a freeboard of 1m will be allowed. These freeboards will allow for debris and hence prevent a significant increased in residual risk in upstream areas as a result of the Proposed Scheme.

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